1946 CPIA 1998

Chemical Propulsion Information Agency

Bulletin

A DTIC-Sponsored DoD Information Analysis Center

Vol. 24, No. 1, January 1998

Domestic Launch Vehicles Finish Strong

Marred only by the January 17 Delta II vehicle failure at Cape Canaveral, United States launch vehicles had an otherwise performance perfect year in 1997. A total of 37 launch vehicles completed their mission successfully, although unrelated problems resulted in the partial or complete loss of a few payloads. The table at the bottom center of the page presents the number of successful launches by vehicle.

Following the Air Force's intensive investigation which cited the case failure of one of nine graphite epoxy booster motors during the January launch, Delta II's return-to-flight was accomplished in less than four months with a successful May 5th launch from Vandenberg AFB. Delta completed the second half of the year at a blistering pace of nearly two launches per month, evenly distributed between the east and west coast sites. Seventeen Delta launches are planned for 1998, including the first Delta III.

Atlas continued its string of successful launches, with eight launches from Cape Canaveral Air Station in 1997. Atlas launches will resume at the west coast site this year after a two year absence from Vandenberg due to construction of new Space Launch Complex 3E (SLC-3E). Nine total Atlas launches are forecast for 1998.

Titan inaugurated its Solid Rocket Motor Upgrade (SRMU) boosters with a successful IVB configuration launch from the Cape on February 23rd. This same "IVB" configuration successfully launched the much-publicized Cassini and Huygens probes in October. Three Titan IV's in a row were launched in the 23-day period between October 15 and November 7, setting a new launch frequency record for this heavy-lift vehicle.

Other vehicles adding to the tally in 1997 were the Pegasus XL which logged five successful launches from the Canary Islands to Wallops Island, VA to Vandenberg; the first operational flight of the Athena I (formerly LMLV-1); and eight missions for America's manned Space Shuttle.

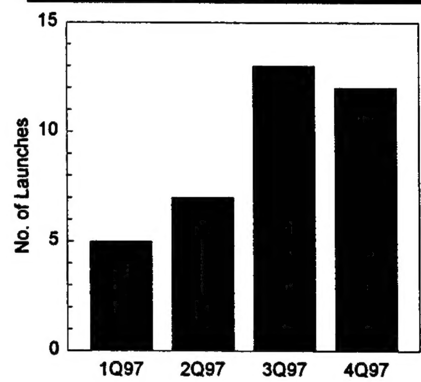
This year should prove to be another banner year for U.S. launch vehicles, as the pace established by a record-setting third and fourth quarters of 1997 will carry into 1998. The activity chart at upper right depicts the marked increase in launch activity during 1997. Early 1998 will see the initial launch of the Athena II as well as planned Pegasus, Atlas, Delta, Taurus and Titan flights.

1997 U.S. Launch Breakdown*

Athena I:	1
Atlas I:	1
Atlas IIA:	1
Atlas IIAS:	6
Delta II:	10
Pegasus XL:	5
Space Shuttle:	8
Titan II:	1
Titan IVA:	2
Titan IVB:	2

*Assumes completion of late December 1997 manifest of one Delta II and one Pegasus XL.

U.S. LAUNCH ACTIVITY BY QUARTER



Happy New Year!

Contents:

CPIA's Technical/ Bibliographic Inquiry Service

CPIA offers a variety of services to its subscribers, including responses to technical/bibliographic inquiries. Answers are usually provided within three working days, and take the form of telephoned, telefaxed, or written technical summaries. Customers are provided with copies of JANNAF papers, excerpts from technical reports, bibliographies of pertinent literature, names of recognized experts, propellant/ingredient data sheets, computer program tapes and instructions, and/or theoretical performance calculations. The CPIA staff responds to nearly 800 inquiries per year from over 180 customer organizations. CPIA invites inquiries via telephone, fax, or letter. For further information, please contact Bill Hufferd at (410) 992-7306, x. 203 or E-mail: hufferd@jhunix.hcf.jhu.edu.) Subjects covered in recent inquiries include:

Technical Inquiries

- Intermediates formed in 2-NDPA-stabilized double-base propellant formulations
- AIM-54 Phoenix aerodynamic characteristics
- Environmental impact of liquid fuels on water and soil quality
- State of solid propellant technology, development, and research
- Thermal properties of silica phenolic

Bibliographic Inquiries

- Solid gun propellant processing and rheology
- Materials compatibility with hydrazine
- Sprayable or paintable elastomeric sealants for composite tanks
- HTPB propellant cure studies
- Propellant cracking

Expendable Launch Vehicle Propulsion Systems

CPTR 97-66

Now available! This technical report, reviewed in November 1997 *Bulletin,* presents commercial launch service market projections in detail and examines international launch service propulsion technology, including the programs of Japan, China, Europe, and Russia. The history of U.S. ELV development is also presented. Contact Dottie Becker (410) 992-7302, Ext. 204 or E-mail: dlbecker@jhunix.hcf.jhu.edu.

Watch Out For The Series

Bulletins throughout the year will include a series of articles, some from guest authors covering topics like U.S. Government Space Launch Operations; Developing National & International Spaceports and Space Launch Options; 1998-1999 World-Wide Commercial Launch Manifest; and Analysis of Global Commercial Launch Capability/Commercial Launch Demand Projections.

The Chemical Propulsion Information Agency (CPIA), a DoD Information Analysis Center, is sponsored and administratively managed by the Defense Technical Information Center (DTIC). CPIA is responsible for the acquisition, compilation, analysis, and dissemination of information and data relevant to chemical, electric, and nuclear propulsion technology. In addition, CPIA provides technical and administrative support to the Joint Army-Navy-NASA-Air Force (JANNAF) Interagency Propulsion Committee. The purpose of JANNAF is to solve propulsion problems, effect coordination of technical programs, and promote an exchange of technical information in the areas of missile, space, and gun propulsion technology. A fee commensurate with CPIA products and services is charged to subscribers, who must meet security and need-to-know requirements.

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Operating under Contract: SPO700-97-D-4004

The New NIMIS-II Software is Offered for Beta Release

The National Insensitive Munitions Information System (NIMIS-II) is a working and fielded analysis tool, specifically designed to provide the weapons development community with a centralized source of Insensitive Munitions (IM) test data and other related information. In order to avoid duplication of costly testing and to centralize the available IM test data, a national reposi-tory of these data was developed. This multi-service system comprises all IM testing and related work, to include such data as: Baseline test, "for score" and not "for score," generic weapons development test, as well as energetic materials test and qualification data. With a user base of over 500 users, this system has a proven track record of providing timely data to developers and managers on specific IM issues. It has served as a valuable tool to scientists, engineers, and managers throughout the weapon life cycle process. Serving as a repository of a broad data spectrum, NIMIS-II is a powerful analysis tool for those engaged in solving IM design problems.

The NIMIS-II system may be obtained by contacting the NIMIS-II Technical Co-ordinator, Mrs. Carolyn Dettling of the Naval Air Warfare Center at (760) 939-7629 or the Database Administrator, Mrs. Cynthia Lundstrom of Booz-Allen and Hamilton, at (703) 412-7471. The current NIMIS-II system is distributed on diskette and requires installation onto a local hard drive. *Distribution is authorized to Government agencies and their Contractors.*

If you would like an invitation to the July 1998 JPM in Cleveland, OH please contact Debra Eggleston @ 410-992-7300 x202 *or* dse@jhunix.hcf.jhu.edu, *or* complete the form on our web page @ http://www.jhu.edu/~cpia/

The *Bulletin* Board

The following are various meetings and events. We welcome all such announcements, so that the propulsion community can be better served with timely information. See CPIA's Homepage "Calendar of Events" link (URL=http://www.jhu.edu/~cpia/).

Dates 1998	Topic	Sponsor	Location
1/12-15	36th AIAA Aerospace Sciences Meeting and Exhibit	AIAA	Reno, NV
1/20-22	Strategic and Tactical Missile System Conference	AIAA	Monterey, CA
2/23-27	Fundamentals of Shaped Charges: Short Course on Explosive Technology	CMA	Baltimore, MD
3/16-20	JANNAF Structures and Mechanical Behavior Subcommittee, Non-Destructive Evaluation Subcommittee, Rocket Nozzle Technology Subcommittee Joint Meetings	CPIA	Salt Lake City, UT
4/20-23	39th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference AIAA/ASME/AHS Adaptive Structures Forum	AIAA	Long Beach, CA
4/21-23	1998 JANNAF Propellant Development & Characterization and Safety & Environmental Protection Subcommittee Joint Meeting	NASA	Houston, TX
4/27-30	8th International Space Planes and Hypersonic Systems and Technologies Conference	AIAA	Norfolk, VA
5/4-6	Global Air & Space '98 Conference	AIAA	Arlington, VA
5/24-28	11th Symposium on Chemical Problems Connected with Stability of Explosives	SNMCI	?Margretetorp, Sweden?
6/30-7/3	29th Annual ICT Conference: Energetic Materials - Production, Processing and Characterization	ICT	Karlsruhe, Germany
7/13-15	34th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit	AIAA	Cleveland, OH
7/15-17	1998 JANNAF Propulsion Meeting	CPIA	Cleveland, OH
7/27-31	24th International Pyrotechnic Seminar	IIT	Monterey, CA
8/30-9/4	11th Detonation Symposium	NIMIC	Aspen, CO
11/9-13	JANNAF Exhaust Plume Technology Subcommittee and SPIRITS Users Group Meeting	CPIA	Kennedy Space Center, FL

AIAA = American Institute of Aeronautics and Astronautics, (703) 264-7500
CPIA = Chemical Propulsion Information Agency, (410) 992-7300, x. 202
CMA = Computational Mechanics Associates, (410) 532-3260
ICT = Fraunhofer-Institut fur Chemische Technologie, +49 - (0)721-4640 - 0
IITRI = IIT Research Institute, (630) 790-9526
JANNAF = Joint Army-Navy-NASA-Air Force; call CPIA at (410) 992-7300, x. 202
JHU/APL = Johns Hopkins University/Applied Physics Lab, (410) 792-5000
NASA = NASA Johnson Space Center, call CPIA at (410) 992-7300, x. 202
NIMIC = NATO Insensitive Munitions Information Center, (32)(2) 728.5416

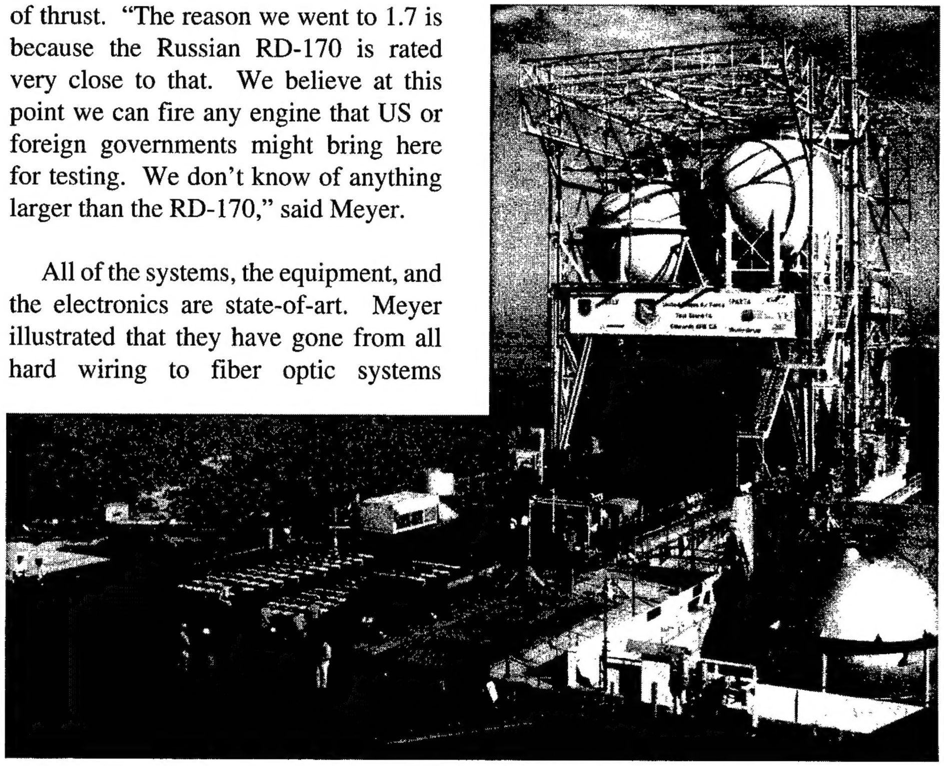
Test Stand 1A Revitalized After 25 Years

A ribbon-cutting ceremony October 2, 1997 marked the completion of improvements toTest Stand 1A, located at the Air Force Research Laboratory-Propulsion Directorate facilities at Edwards AFB. The first engine hot firing is scheduled for early 1998. In a telephone interview Nov. 14, Lee Meyer, acting director said, "If you constructed a new test stand of this kind, it would cost around $150 million and we refurbished it for 10 percent of that."

The stand's refurbishment supports the propulsion testing efforts of Boeing North American Division Rocketdyne's EELV program; one of two firms awarded half the remaining EELV development funds by the Air Force. The Air Force previously planned to award only one firm (either Boeing or competitor Lockheed Martin) $1.3 billion to complete its vehicle.

The test stand reaches 26-stories from the bottom of the flame bucket all the way to the top of the superstructure. In comparison, the Statue of Liberty (although not sitting on the edge of a cliff) extends 22-stories to the Statue's crown. This test stand is an enormous structure configured to restrain 1.7 million pounds of thrust. "The reason we went to 1.7 is because the Russian RD-170 is rated very close to that. We believe at this point we can fire any engine that US or foreign governments might bring here for testing. We don't know of anything larger than the RD-170," said Meyer.

All of the systems, the equipment, and the electronics are state-of-art. Meyer illustrated that they have gone from all hard wiring to fiber optic systems including touch screen controls. "In the control room, if you look at the TV monitor you have a valving system displayed and you just touch the valve you want open and the system will respond," said Meyer. The advantage of digital data is that it's more accurate and can be displayed on the monitor or by a print out. He emphasized that hard wiring lines are still available for high frequency data acquisition. Aside from the state-of-art equipment, another ideal aspect about Test Stand 1A is that there are no envionmental limitations that keep them from testing. "We comply with all regulations in effect at this time," Meyer stated. He stressed their strength in team work as another advantage point.



Test Stand 1A, Edwards AFB

"We operate differently than we did in the past," said Meyer. He explained that it is a government/industry team and not something where the industry delivers the package, the government does the testing, and then sends them the report. It's not an all government operation. "We have Sverdrup, the on-site contractor that supplements our government man power to run the facility, and then its really a team of government, Sverdrup and the customer," he declared.

Fire and Explosion Hazards of Liquid Propellants

Explosives safety standards for liquid propellants such as liquid oxygen (LOX), liquid hydrogen (LH2), hydrazines, nitrogen tetroxide and other materials used in launch vehicles and some weapons systems are based on information and data comprising the state of knowledge from over thirty years ago. Additional data have been developed from research efforts and analyses conducted since the original criteria were established. In addition, current standards do not specifically address materials such as gelled propellants and concepts such as hybrid rocket systems. In response to these deficiencies, the Department of Defense Explosives Safety Board (DDESB) has initiated the DoD Explosives Safety Standards for Energetic Liquids Program to address issues of explosives equivalence, compatibility mixing, and quantity-distance (Q-D) criteria and to develop recommended revisions to regulations promulgated in DoD 6055.9-STD covering liquid propellants and other energetic liquid materials. Energetic Liquid has been defined as - a liquid, slurry, or gel, consisting of or containing an explosive, oxidizer, fuel, or combination of the above, that may undergo, contribute to, or cause rapid exothermic decomposition (thermal explosion), deflagration, or detonation.

In order to expedite the program, the DDESB is sponsoring a Technical Area Task with CPIA to accomplish a number of projects. As part of the overall effort, CPIA has performed an assessment of fire and explosion effects on the surrounding environment from accidents involving liquid propellant fuels, oxidizers, monopropellants, and bipropellant combinations. The assessment ensures that any proposed revisions to the explosives safety standards covering storage and use of energetic liquids reflect actual hazards observed in historical incidents. Results of tests that simulate real life accident scenarios in both magnitude and failure mode were also considered in the study. This article highlights some of the more interesting accidents identified in the study and summarizes pertinent details with respect to quantity-distance criteria for energetic liquids.

FUELS, OXIDIZERS, AND MONOPROPELLANTS

The first part of the study examined accidents with monopropellants, fuels, and oxidizers when isolated from other incompatible energetic liquids. Table 1 (on page 6) compiles information on the number of incidents identified with various materials of interest, the incident failure scenarios involved, and some brief observations on hazard characteristics observed.

These materials demonstrated a wide variance in degree of hazard. Although a blast hazard was inferred at relatively close range for liquids such as hydrazine and HAN based materials (depending on confinement), the primary hazard (without consideration of toxic hazards) governing quantity-distance requirements for these materials appears to be fragment throw for static situations such as liquid storage. This behavior is due to a propensity towards self sustained decomposition (as a negative characteristic) but shock insensitivity and resistance to mass detonation (as positive characteristics - relative to typical high explosives). While quantitative information on blast and fragment effects from analogous incidents with hydrogen peroxide, ethylene oxide, and Otto Fuel II was not obtained, these materials exhibit a similar characteristic of self reactivity and thus may be considered to produce similar hazard effects (to hydrazine or HAN) in a storage environment. Complete discussion of this subject is beyond the scope of this article, however.

Liquids such as ethylene oxide and Otto Fuel II may also exhibit more predominant blast hazards in situations involving pumping or propulsion system testing due to vapor explosions or other unique effects. Likewise, nitromethane and monomethylamine nitrate may also exhibit significant blast hazards in circumstances involving bulk quantities of the materials. On the other hand, the primary hazard with materials such as nitrogen tetroxide, nitric acid, chlorine trifluoride, and liquid hydrogen appears to be either normal fire or dispersion of toxic vapors from the unreacted materials. These materials did not exhibit a susceptibility to violent self decomposition similar to the other energetic liquids.

LIQUID BIPROPELLANT LAUNCH VEHICLES

A significant database of explosion accidents involving the hydrocarbon propellant RP-1 in combination with liquid oxygen (LOX) has been identified. These include several launch failures involving Atlas, Thor, Jupiter, Vanguard, and Navaho missiles, an on-pad failure of an Atlas 9C vehicle, and a tank overpressurization failure with a Thor missile. In addition, the liquid propellant hazard test program Project Pyro included a large scale confinement-by-missile (interior tank bulkhead rupture) failure test simulating a Titan I missile first stage incident. The Thor tank overpressurization and Atlas 9C incidents also represent confinement-by-missile failure as defined in Project Pyro.

Three data points with liquid propulsion systems containing a combination of liquid hydrogen (LH2) and LOX were identified. Two propellant tank confinement-by-missile (interior tank bulkhead rupture) failure accidents occurred during preparations for static tests of Saturn V vehicle propulsion stages in 1964 and 1967. In addition, a full scale Saturn stage was also tested to similar confinement-by-missile failure during Project Pyro.

(continued on page 6)

Table 1. Incidents With Monopropellants, Fuels, and Oxidizers

Material	# Incidents	Failure Scenario	Hazard Characteristics
Hydrazine	3	explosion of storage drums or propellant tanks in fire	violent explosion with pressure vessels (near field blast); no mass sympathetic reaction; far field fragment hazards
Otto Fuel II	3	fuel tank explosion during static testing; explosion in tranfer pipeline in fire; explosion of propellant tank in fire	finite propagation of low velocity detonation with heavy confinement or ullage (blast and fragement hazards similar to HE); minor explosion with lower confinement (near field fragment hazards)
Ethylene Oxide	4	major chemical plant explosion; minor sterilization facility explosion; fire from ruptured tank car or pipeline	major vapor explosion at chemical plant (probable blast and fragment hazards); possible near field fragment effects from minor explosions otherwise
Liquid Hydrogen	5	fires from ruptured pipeline or processing equipment	fire only
Hydroxylammonium Nitrate	4	spontaneous explosion of storage tanks, processing vessels, or pipeline	violent explosion with pressure vessels (near field blast); no mass sympatheic reaction; near field fragment hazards
Chlorine Trifluoride	1	minor explosion and toxic cloud release from static test run tank	primarily toxic cloud hazards
Hydrogen Peroxide	7	fires/explosions with storage drums, processing vessels, and misc aerospace system testing	minor explosions causing localized damage; no mass reaction; potential near field fragment hazards
N204/IRFNA	5	toxic cloud releases from tanks	toxic cloud hazards only
Monomethylamine Nitrate	1	major explosion of rail tank car	major explosion
Nitromethane	1	major explosion of rail tank car	major explosion

Finally, one well characterized explosion accident involving an Atlas Centaur vehicle was identified. The Atlas Centaur launch failure scenario proceeded as follows. The vehicle lost thrust at about 1.5 seconds after lift-off at an altitude of four feet. The vehicle fell straight down while maintaining an upright attitude. A total of six sequential explosions were reported during the ensuing event, including four relatively minor reactions. Significant explosions of the main Atlas stage, containing approximately 254,000 pounds of RP-1/LOX propellant combination, followed by the Centaur stage containing 30,000 pounds of LH2/LOX propellant combination, also occurred with a small but distinguishable time delay. The far field blast wave properties observed in this incident are probably due to coalescence of the waves from the RP-1/LOX and LH2/LOX explosions.

The explosion effects from liquid hydrogen/hydrocarbon bipropellant and tripropellant systems can be related to conventional explosive ammunition when adjusted for equivalent high explosive quantity. Table 2 (on page 7) shows example TNT equivalency values determined for these propellant combinations from incidents with some representative systems. Considering observed fragment dispersion data from the explosion events (not discussed herein), minimum distances of approximately 1100 feet may be required to avoid fragment hazards. Furthermore, since substantial blast effects can be realized from large quantities of these propellant systems, a threshold propellant quantity may exist where blast hazards become predominant at even greater distances based on the TNT equivalence of the propellant combination. A thorough, independent statistical analysis of TNT

(continued on page 7)

Fire and Explosion Hazards... *(continued from page 6)*

equivalence data as a function of propellant quantity and failure scenario for cryogenic bipropellant and tripropellant explosions from both accidents and test programs has been performed. Results of this study are being considered in the overall DDESB effort.

One explosion incident involving large quantities of the hypergolic propellant combination of Aerozine 50 (50/50 mixture of hydrazine and unsymmetrical dimethylhydrazine) and nitrogen tetroxide has been well characterized. The incident occurred during in-silo maintenance activities with an operational Titan II missile. A leak in the Stage 1 fuel tank proceeded for over eight hours, releasing approximately 3700 gallons of A-50 such that flammable A-50 vapors diffused throughout the silo complex. An unknown ignition source triggered a vapor fire in the silo equipment area that propagated to the launch duct, causing an explosion of the confined vapors there. The vapor explosion was strong enough to rupture the Stage 1 nitrogen tetroxide tank aft dome resulting in a confinement-by-missile propellant mixing failure scenario and a major hydrazine fuel/nitrogen tetroxide explosion in the intertank region. Analysis of the event determined the TNT equivalency of the propellant combination to be approximately 1% (ignoring confinement and shock focusing effects caused by the silo environment). One large (actually one half) scale Titan II Stage 1 model destruct test also provides relevant data. The test simulated a confinement-by-missile failure scenario (not in-silo) by simultaneously rupturing both fuel and oxidizer tanks (in the intertank region). The maximum TNT equivalence calculated for the event was less than 1%. Unfortunately, a straightforward analogy to conventional explosive ammunition hazards related to quantity distance requirements was not observed for hypergolic propellant systems.

A few data points characterizing the hazards of small, hypergolic fueled tactical missile propulsion systems were also obtained; however, these will not be discussed here.

A complete technical report from this project has been published as CPIA Publication 661 entitled *Fire and Explosion Hazards of Liquid Propellants And Related Materials - An Accident Review*, October 1997. The report summarizes pertinent data in greater detail from each accident identified, and includes additional observations examining categorization of these materials with respect to specific quantity distance criteria. The report is available to qualified CPIA subscribers by contacting Ms. Dorothy Becker of CPIA at (410) 992-7302. To discuss the technical nature of this project, contact Mr. James Cocchiaro at (410) 992-9950 (X208).

Jim Cocchiaro

Table 2. TNT Equivalence of Cryogenic Propellants

System	Propellant	Propellant Weight (lb)	FailureMode	Average TNT Equivalence (%)
Atlas	RP-1/LOX	250,000	Launch	1 - 7 (14% max)
Thor	RP-1/LOX	100,000	Launch	1 - 3
Vanguard	RP-1/LOX	16,000	Launch	3
Navaho	RP-1/LOX	76,000	Launch	1
Jupiter	RP-1/LOX	94,000 - 120,000	Launch	5 - 11
Thor	RP-1/LOX	100,000	CBM	2
Titan I	RP-1/LOX	94,000	CBM	3
Saturn V	LH2/LOX	91,000 - 231,000	CBM	1 - 4
Atlas Centaur	RP-1/LH2/LOX	284,000	Launch	4 (9% max)

Meeting Peeks!

Please Go Home to CPIA's Meeting Review Section (http://www.jhu.edu/~cpia/)

1997 Joint JANNAF CS/PSHS/APS Meeting

The 1997 meetings of the JANNAF 34th Combustion Subcommittee (CS), the Propulsion Systems Hazards Subcommittee (PSHS), and the Airbreathing Propulsion Subcommittee (APS) were jointly held 27-30 October 1997 at the Palm Beach Gardens Marriott Hotel in West Palm Beach, Florida. The meeting was hosted by United Technologies Pratt & Whitney, with Mr. George Cox serving as meeting site host. Mr. Thom Boggs of the Naval Air Warfare Center, China Lake, California, served as the joint Meeting Chairman. The technical program chairmen were: Mr. Jay N. Levine (PL, Edwards AFB), Dr. Robert B. Frey (ARL), and Mr. Parker Buckley (WL, WPAFB) for the CS, PSHS, and APS, respectively. Over 340 engineers, scientists and program managers attended.

The meeting opened with a welcoming address by Mr. Dennis Mills, Director of Liquid Rocket Engines at Pratt & Whitney. Opening ceremonies included the presentation of a Combustion recognition award to Mr. David Mann, ARO, Propulsion Systems Hazards recognition awards to Ms. Susan DeMay of the Naval Air Warfare Center/China Lake and Mr. John Corley of the Air Force Research Laboratory, Eglin AFB, FL, and an Airbreathing Propulsion recognition award to Mr. Raymond Cosner, Boeing, St Louis, all for outstanding contributions to JANNAF and their respective subcommittees.

Over 250 papers were presented in 35 technical sessions, which included two CS/PSHS and ten APS/CS jointly sponsored sessions and one jointly sponsored workshop.

The CS technical program had 151 papers presented in 28 technical sessions. Technical topics included combustion kinetics; fundamentals and instability of solid propellants containing AP & metals; bi-plateau propellant combustion; combustion instability fundamentals and applications in solid rocket motors; liquid & hybrid rocket combustion; measurement techniques; formulation, ignition, combustion, and interior ballistics associated with solid gun propellants; ignition and combustion modeling, diagnostics and charge concepts for electro-thermal guns; combustion, interior ballistics and testing of regenerative liquid propellant guns; advanced combined cycle propulsion; Hyper-X & high speed missile technology; ram/scramjet design methodologies; ram/scramjet component & engine testing and modeling & simulation; current & advanced hypersonic fuels; inlet technology; thermal management of advanced systems; and conventional liquid fuel ramjet and variable flow ducted rocket engine. Three CS town meetings were conducted in the areas of solid, liquid and gun combustion to discuss topics of current interest and to select future workshop topics.

The meeting of the Solid Rocket Combustion Instability Panel discussed FY1998 workshops and the areas of motor flow and propellant response testing. Topics of discussion for the Liquid Rocket Engine Injector Panel and Kinetics Panel focused upon selection of new panel chairs, Kevin Tucker, NASA/MSFC and Rich Behrens, SNL, respectively, and future work tasks. The Kinetics Panel intends to focus efforts on condensed phase kinetics, having resolved gas phase kinetics to a reasonable degree of understanding.

The PSHS technical program included presentations of 41 papers in six sessions. These technical sessions covered vulnerability of granular gun propellants; vulnerability of liquid and unconventional solid propellants; thermal decomposition and cookoff phenomena; impact explosive hazards of solid rocket propellants; processing hazards associated with various demilitarization operations; and violent reaction/detonation phenomena with energetic materials. While all of the sessions included presentation of excellent technical work, three sessions in particular illustrated the importance of the coordination of research and presentation of pertinent work through JANNAF activities. The thermal decomposition/cookoff session featured several papers describing research being performed to examine the thermal, mechanical, and ballistic properties of energetic materials at elevated temperatures and pressures. These data are needed by the modeling community to provide adequate physical understanding of the cookoff problem and to validate cookoff models under development. The impact explosion hazards session featured papers on development of data and modeling techniques to characterize the blast hazards of Class 1.3 rocket propellants under ground impact (for range safety considerations). The results reported were a culmination of the PIRAT (Propellant Impact Risk Assessment Team) research program sponsored by the Launch Vehicle Program Office of the

From Left to Right: Edward Lee (Lee and Associates), Jon L. Maienschein and Jack Reaugh (LLNL, Livermore, CA), Ronald F. Dettling (Sverdrup, Inc., Edwards AFB, CA), Claude Merrill (Air Force Research Lab, Edwards AFB, CA), Robert L. Geisler (Geisler Enteprises/Sparta, Tehachapi, CA)

(continued on page 9)

Meeting Peeks! (1997 Joint JANNAF...) *(continued from page 8)*

US Air Force Space and Missile Center (SMC). Following the presentations, awards for outstanding work on the PIRAT program were presented on behalf of the Launch Vehicle Program Office of SMC to representatives of several organizations including SRS Technologies, Phillips Laboratory/Edwards AFB, Sverdrup Technologies, Lawrence Livermore National Laboratory, Research Triangle Institute, The Aerospace Corporation, USAF 45th Space Wing, SMC, ACTA Incorporated, and TRW Incorporated. Finally, the liquid propellant vulnerability session included several papers addressing commonality of phenomena important to the hazard response of liquid propellants used in diverse applications such as liquid propellant guns and torpedo propulsion systems.

Meetings of the Cookoff Hazards Panel and Safety & Hazard Classification Panel were also held during the week. The Cookoff Panel discussed experimental activities at different facilities (being coordinated through PSHS) to support and advance the development of energetic material cookoff hazard prediction modeling techniques. The meeting was prompted by discussions among different organizations relative to defining small scale validation experiments that will provide data sets on violence-of-reaction that could be used to evaluate sub-models and capabilities of the ALE3D, COYOTE/JAS, and ALEGRA/CTH computer codes for cookoff prediction. The Safety & Hazards Classification Panel met to discuss further efforts related to the development of consensus and rationale (methodology and supporting data) for assigning TNT equivalence (for range safety considerations) to fallback/ground impact scenarios with large Class 1.3 rocket motors and propellants. Finally, an impromptu technical interchange meeting on issues related to insensitive munitions test philosophy and hazard assessment protocol was held.

The APS technical program consisted of 11 sessions with 51 papers. Technical session topics included advanced combined cycle propulsion, Hyper-X & high speed missile technology, ram/scramjet design methodologies, ram/scramjet component & engine testing, ram/scramjet modeling & simulation, current & advanced hypersonic fuels, inlet technology, thermal management of advanced systems, and conventional liquid fuel ramjet and variable flow ducted rocket engine. A joint APS/CS airbreathing town meeting was held to discuss topics of current interest and to select future workshop topics. A jointly sponsored APS/CS workshop on "Modeling & Simulation" was conducted by Dr. John Porter, Sverdrup.

Meetings of four APS panels were conducted during the week, including the Advanced Engine Cycle Panel, the Testing & Validation Panel, the Modeling & Simulation Panel and the Fuels Panel. The Advanced Engine Cycle Panel discussed the formation of working groups focusing on four key engine cycles of: scramjets & high speed; rocket-based combined cycles; pulse detonation engines; turbine & turbine-based combined cycle. Each working group will be comprised of active participants from the propulsion community. The Test & Validation Panel is refocusing their efforts to complete scramjet test guidelines. The Modeling & Simulation Panel is moving to broaden their focus which has recently completed the task of developing a recommended JANNAF process for validating CFD codes. The Fuels Panel under new leadership, Tim Edwards, WL met to review future activities which include expansion of the fuels section of the CPIA/M6 Airbreathing Propulsion Manual, and a fuels brochure to support ongoing system developments. Major Dave Hazelton of the AFRL at WPAFB became APS chairman, replacing Parker Buckley, who is a newly appointed member of the JANNAF Executive Committee.

Proceedings of the CS, PSHS and APS meetings will be published separately by CPIA and will be available in March 1998. All proceedings will include the papers presented in joint sessions. To order the proceedings, call Dorothy Becker (CPIA) at (410) 992-7302 x204.

IHPRPT Briefing for Industry

The NASA Marshall Space Flight Center and the Army Aviation and Missile Command hosted the first Integrated High Payoff Rocket Propulsion Technology (IHPRPT) Briefing for Industry (BFI) 7-9 October 1997. This review consisted of briefings of government in-house research and development activities being conducted in support of the IHPRPT program. Thirty-nine presentations were made by Army, Navy, NASA and Air Force researchers. An additional 14 papers were presented in an evening poster session. Approximately 75 industry and government representatives attended, which provided a forum for industry to critique and provide feedback on government in-house R & D activities.

The Integrated High Payoff Rocket Propulsion Technology program is a joint DoD-NASA-Industry program to double the U.S. rocket propulsion capability by the year 2010. Planning for the IHPRPT program began in 1992 and the nationally accepted program was finalized in 1996. The objective of the program is to strengthen the technology base of the U.S. military, civil and commercial rocket programs through the development of advanced, innovative rocket propulsion technology. For more information about IHPRPT, please contact Mr. Drew DeGeorge at (805) 275-5340.

AGARD/PEP Evaluation of Methods for Solid Propellant Burning Rate Measurements, Brussels Meeting

The third meeting of the AGARD/PEP Working Group #27 "Evaluation of Methods for Solid Propellant Burning Rate Measurements" was held 21-23 October 1997 at NATO Headquarters in Brussels, Belgium.

(continued on page 10)

Meeting Peeks! (AGARD/PEP...) *(continued from page 9)*

Six NATO countries are actively participating. The working group is Chaired by Rene Couturier of SNPE. The US technical representatives on the working group are Dr. Robert Frederick, University of Alabama in Huntsville, and Ronald Fry, The Johns Hopkins University/Chemical Propulsion Information Agency.

The objectives of the working group are to review and compare methods for measuring steady-state burning rate of solid rocket propellant through current practice and advanced techniques. The overall focus of the working group is approximately 70% small motors, 25% advanced diagnostics and 5% other methods including strand burners. An AGARD Advisory Report to the NATO community will be produced containing information and recommendations useful to a wide range of technologists and managers.

Progress to date included presentations and discussions of draft chapters of the advisory report. Chapter topics include burning rate physics, features and stability; measurement techniques & hardware; analysis methods; advanced measurement methods; and scaling assessments. The burning rate versus average pressure results of an Analysis Round Robin were reviewed by the working group. All the participants calculated burning rate results followed the expected model results. Variations in calculated average pressure were observed based on differences in analysis methods. It was decided to conduct a second round robin analysis to better clarify the observed differences in methods and their sources. The approach will involve analyzing "simulated" motor pressure-time data for basic motor parameters. Each case will be analyzed using multiple methods, such as web/time, iterative and mass balance.

Working group action items included tasking chapter authors with making changes and providing updates, soliciting inputs from chapter contributors and completing the Analysis Round Robin II prior to the next meeting, scheduled for Toulouse, France 11-15 May 1998. Your assistance in supporting this worthwhile NATO project is appreciated and will be acknowledged. Please contact Ronald Fry at (410)992-9951 or e-mail rs_fry@jhunix.hcf.jhu.edu if you have information to contribute.

ONR Pulse Detonation Engine Workshop

A Pulse Detonation Engine (PDE) Workshop was held on 10 October 1997 at the Naval Postgraduate School (NPS) in conjunction with the 10th Office of Naval Research (ONR) Propulsion Meeting. The workshop was requested and sponsored by Dr. Gabriel Roy of ONR and chaired by Professor David Netzer of the NPS.

The objective of the workshop was to develop and prioritize basic research needs for the PDE. Each invited participant presented a five minute overview of their current PDE efforts and a ten minute discussion of basic research that needs to be conducted if the PDE is to achieve its maximum potential as a propulsion device. The workshop had over sixty-five participants.

The basic research needs presented at the workshop were assembled into a list and distributed to the participants for ranking. Rankings from highest to lowest in priority resulted from over forty-percent of the participants responding. Six topics combined to reflect over 53% of the basic research needs, which included (1) Two-Phase Detonation Physics (12.1%); (2) Fuel Management (9.4%); (3) Thermodynamic Cycle Analysis (8.6%); (4) Gaseous Detonation Physics (8.1%); (5) Computational Fluid Dynamics(8%); and (6) Non-Steady Inlet Flows/Combustor-Inlet Interactions (7.1%). Thirteen additional topics were identified to round out the list of basic research needs. A complete listing is available on the CPIA homepage (http://www.jhu.edu/~cpia/).

JANNAF Subcommittee Meeting Reminders

March 16-20, 1998
Salt Lake City, Utah

Nondestructive Evaluation (NDES),
Rocket Nozzle Technology (RNTS),
Structures & Mechanical Behavior (S&MBS), plus
Reusable Solid Rocket Motor (RSRM)
Nozzle Erosion Specialist Session

For more information contact
Mary Gannaway @ 410-992-7304 x211

April 21-23 1998
Houston, Texas

Propellant Development & Characterization (PDCS)
and
Safety & Environmental Protection (S&EPS)

For more information contact
Dorothy Becker @ 410-992-7302 x204

Meeting Preview

JANNAF Coming to Salt Lake City in March!

The Best Western Olympus Hotel Conference Center in downtown Salt Lake City is the site for the March 16-20, 1998 joint meeting of the **Nondestructive Evaluation Subcommittee (NDES), Rocket Nozzle Technology Subcommittee (RNTS), and the Structures & Mechanical Behavior (S&MBS).** Over 100 technical presentations have been scheduled for the first meeting of these three subcommittees since December 1996. The NDES meeting will comprise the following three full sessions: NDE Systems Applications, Aging Systems and Health Monitoring, and New NDE Technologies. A third consecutive workshop on Advances in Digital Imaging will be held.

Over 50 technical presentations are scheduled for RNTS, which will feature sessions on Nozzle Design, Test, and Evaluation; Processing Science and Materials; Nozzle Analysis and Modeling; Cost, Volume, and Weight Reduction for Thrust Vector Control; and Thrust Management Control Systems. A large portion of the RNTS program will be devoted to the presentation of findings associated with the investigation of unusual erosion observed in three **Reusable Solid Rocket Motor (RSRM) nozzles.** This JANNAF meeting will offer the only conference-style forum for the comprehensive presentation of analyses and test data generated by the government and industry team.

Over 30 papers have been scheduled for the S&MBS sessions with particular emphasis on propulsion system aging and service life issues. Focused sessions on analytical tools for failure investigation are also planned. Additionally, local propulsion facility and NDE tours of interest will be offered, and an informal evening social event will be held at the historical Park City Silver Mine.

Meeting registration information and the preliminary program were mailed to the JANNAF subcommittees' mailing list in late December. Prospective attendees who have not received a program may request one by calling Mary Gannaway at (410) 992-7304 ext. 211, or you may access it via CPIA's web site at www.jhu.edu/~cpia/.

LMLV Becomes Athena

The Lockheed Martin Launch Vehicle has been named after the Greek goddess **Athena** according to a press release from Lockheed Martin Astronautics of Denver. Dr. Raymond Colladay, president of LM Astronautics, commented that Athena's attributes of wisdom, intellect, invention, industry and skill match those demonstrated by the team which created and manages the vehicle.

America's newest launch vehicle became operational with the successful launch of an Athena I on August 22, 1997 from Vandenberg Air Force Base, California. At press time, the launch of an Athena II from Cape Canaveral Air Station was scheduled for January.

In Memory of Bo Stokes

CPIA is deeply saddened by news that Mr. Benjamin (Bo) Stokes and his wife Carolyn were killed recently in a car accident in New Zealand. Bo was currently working as a Technical Officer at the NATO Insensitive Munitions Information Center, Brussels, Belgium. Prior to taking that position in 1991, he was employed for many years at Thiokol Corporation in Huntsville, Alabama. Our condolences are with his family in these difficult times.

CPIA Bulletin

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JANNAF MEETING CALENDAR

1998	Meeting	Type	Location	Abstract Deadline	Paper Deadline
Mar 16-20	Structures and Mechanical Behavior Subcommittee, Nondestructive Evaluation Subcommittee, Rocket Nozzle Technology Subcommittee Joint Meetings	Conference/ Workshops/ Specialist Sessions	Salt Lake City, UT	Oct 17 SMBS Oct 31 NDES/RNTS	Feb 20
Apr 21-23	Propellant Development and Characterization Subcommittee and Safety and Environmental Protection Subcommittee Meeting	Conference	Houston, TX	Oct 17	Mar 30
Jul 15-17	1998 JANNAF Propulsion Meeting	Conference	Cleveland, OH	Sep 8	May 22
Nov 9-13	JANNAF Exhaust Plume Technology Subcommittee and SPIRITS Users Group Meeting	Conference	Kennedy Space Center, FL	Jun 1	Oct 19

Attendance at JANNAF Conferences and Workshops is by invitation only.

MEETING CALENDAR SUBJECT TO CHANGE. FOR LATEST DETAILS, CONTACT CPIA AT (410) 992-7304.

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